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Rowing on a boat versus rowing on an ergo-meter: a biomechanical and electromyographycal preliminary study

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Abstract

The present preliminary study aimed to report differences between rowing on a boat and rowing on ergo-meter considering not only kinetics and kinematics but also electromyography for a wider understanding of the motor control patterns. Right elbow and knee kinematics of a 23 years old elite rower was recorded by means of two electrical goniometers. Resultant handle force was calculated respectively from strain gauges applied on the right oar and with an uni-axial load cell fixed on the ergo-meter bar. Eight muscles were considered, referred to right arm, right leg and trunk. The athlete was asked to perform 2 minutes rowing on-water at 20 strokes per minute (spm) and 2 minutes at 32 spm. Then he performed the same protocol on the rower ergo-meter. Maximal voluntary contractions were recorded for EMG data normalization. Kinematics showed an increase in the elbow peak flexion (+20.3% at 20 spm and +16.6 % at 32 spm) and a decrease in the knee peak flexion (-4.5% at 20 spm and -2.8% at 32 spm) rowing on the ergo-meter. Peak force recorded at the right hand was higher in the ergo-meter both at 20 spm (+43.5%) and at 32 spm (+29.8%). Muscle activity was higher in the ergo-meter considering biceps brachii, deltoideus medialis, trapezius trasversalis and vastus medialis. Cross-plots of elbow flexion versus muscle activity and versus hand force showed different coordinative patterns comparing the two experimental conditions. Results of this preliminary study indicated the ergo-meter as a valid training device considering the force at the hand. However, it showed different coordinative patterns with respect to rowing on the water in such a way that it should be carefully employed close to competitions.

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Keywords: Rowing; Ergo-meter; Electromyography; Biomechanics

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1. Introduction

A considerable amount of research has been done on the mechanics and biomechanics of rowing [1-3]. Other studies analyzed the biomechanical changes due to the different level of rowers. For instance Hase and colleagues [4] compared 5 university-level competitive rowers and 5 non-rowers on a ergo-meter, collecting kinematics and kinetics data to drive a musculo-skeletal model. Results showed similar patterns comparing the two groups even if the competitive rowers showed a higher knee extension and a lower trunk extension during the drive phase.

Because of weather and water conditions rowers had to perform several indoor training sessions with ergo-meter simulators. For this reason scientific literature compared rowing on ergo-meter and rowing on boat. Dawson and colleagues [5] analyzed the sources of variance and invariance in these two conditions showing that in both conditions the major source of variability was the recovery phase. Moreover it was less on the ergo-meter than on the water. At the same way Kleshnev [6] aimed to identify biomechanical differences and similarities between on-water rowing and its simulation on two different ergo-meters. He founded a higher value of handle force in the two ergo-meters with respect to on-water rowing (30-40%) as well as a shorter stroke length in both the ergo-meters. Differences were also found in the handle velocity and shell acceleration profiles. He concluded that ergo-meters should be considered as a cross-training for rowers and cannot replace on-water rowing.

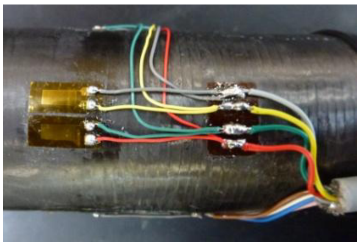
On the basis of these previous investigations, the present preliminary study aimed to report differences between rowing on a boat versus rowing on a Concept2 ergo-meter. We considered knee and elbow kinematics, handle force and surface electromyography of specific muscles involved in rowing for a better understanding of the motor control patterns involved.

2. Methods

2.1. Instrumentations

In order to measure the normal and the tangential forces at the right oar (respectively named RONF, ROTF), 8 strain gauges had been applied directly on the right oar surface and cabled to obtain two full bridges in two perpendicular flexion planes (Figure 1a). The measurement of the force on the ergo-meter (REF) was obtained by means of a ring type load cell positioned between the handle and the chain of the Concept2 ergo-meter (figure 1b).

(a)



(b)

Fig. 1. (a) particular of the strain gauges applied on the oar; (b) ring load cell employed to collect handle force on the ergo-meter.

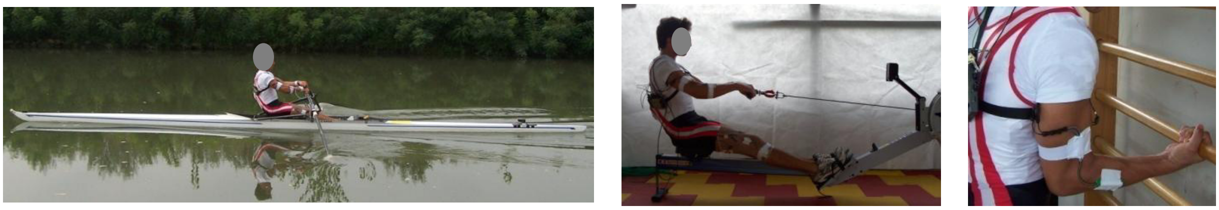
Right knee and elbow flex-extension were collected with two Biometrics® twin axis goniometers. Pre-gelled round electrodes were applied on the skin to record the surface electromyographycal activity (EMG) of 8 muscles. A PDA data logger (BTS Bioengineering, Italy) was employed to synchronously record at 1kHz force data, kinematics data and surface EMG data.

2.2. Test protocol

An elite U23 athlete (Height: 195cm. Weight: 95kg) participated as volunteer at this preliminary study. EMG electrodes were applied on the following muscles of his right side: biceps brachii, pectoralis major, deltoideus medius, latissimus dorsi, trapezius transversalis, erector spinae, vastus medialis and biceps femoris. Prior to the electrodes placement, the skin was accurately shaved and then cleaned with alcohol. Electrodes were placed on the muscle belly with the same inter-electrodes distance. The two goniometers were laterally fixed on the right elbow and on the right leg by means of an hypoallergenic medical tape.

The athlete was asked to perform with his own boat (Figure 2a) two runs of 2 minutes each one, rowing at 20 strokes per minute (spm). Then he had to complete others two runs of 2 minutes rowing at 32 spm. The athletes controlled the spm by means of a NK StrokeCoach®. Once he finished the on-boat runs, he moved in the gym and performed 2 runs of 2 minutes at 20 spm on a Concept2 ergo-meter (Figure 2b). Then he performed the last 2 runs of two minutes at 32 spm on the same ergo-meter.

Finally the maximal voluntary contractions (MVCs) were collected for each of the 8 muscles analyzed (Figure 2c).



(a) (b) (c)

Fig. 2. (a) athlete during a 20 spm run on the boat; (b) athlete during a 20 spm run on the ergo-meter; (c) biceps brachii MVC recording.

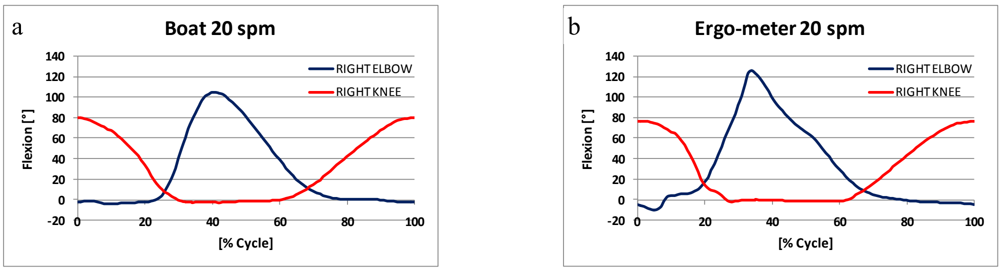
2.3. Data analysis

Knees and elbow angle followed the same convention: when the joints were fully extended their angle corresponded to 0° while flexions assumed positive values both for knee ($+\varphi_k$) and for elbow ($+\varphi_e$). EMG raw signals of the eight muscles were first rectified around their mean value, then integrated with a mobile window of 150ms, filtered with a 5Hz low pass Butterworth filter and finally normalized with respect to the maximal voluntary contractions (MVCs). The resultant handle force referred to the right oar (ROHF) was computed ($\mathrm{ROHF} = \sqrt{\mathrm{RONF}^2 + \mathrm{ROTF}^2}$) and compared to the force measured with the load cell on the ergo-meter (REHF). However, considering that REHF was referred to the traction of both hands on the ergo-meter bar, it was split in half to be comparable with the ROHF.

All signals were normalized to the rowing cycle length. In particular the stroke was defined by two consecutive peaks of knee flexion that corresponded to the catch event.

3. Results

In figure 2 we presented data referred to the knee and elbow kinematics during the trials at 20 spm and at 32 spm. Each curve represented the average of ten consecutive stroke cycles, normalized as explained in the data analysis section. While knee flexion was similar comparing the runs on the boat with those on the ergo-meter, differences could be appreciated concerning the elbow kinematics with a higher flexion when rowing on the ergo-meter.



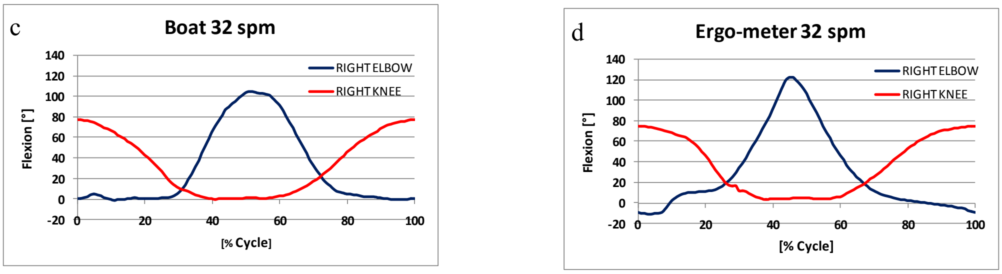


Fig. 3. (a) mean kinematics curves at 20 spm rowing on the boat; (b) mean kinematics curves at 20 spm rowing on the ergo-meter; (c) mean kinematics curves at 32 spm rowing on the boat; (d) mean kinematics curves at 32 spm rowing on the ergo-meter.

Figure 4 reported the comparison of the handle forces collected on the boat and on the ergo-meter. As for the kinematics data, each curve represented the average of ten consecutive stroke cycles. Both at 20 spm and 32 spm the highest peak forces were recorded in the runs on the ergo-meter.

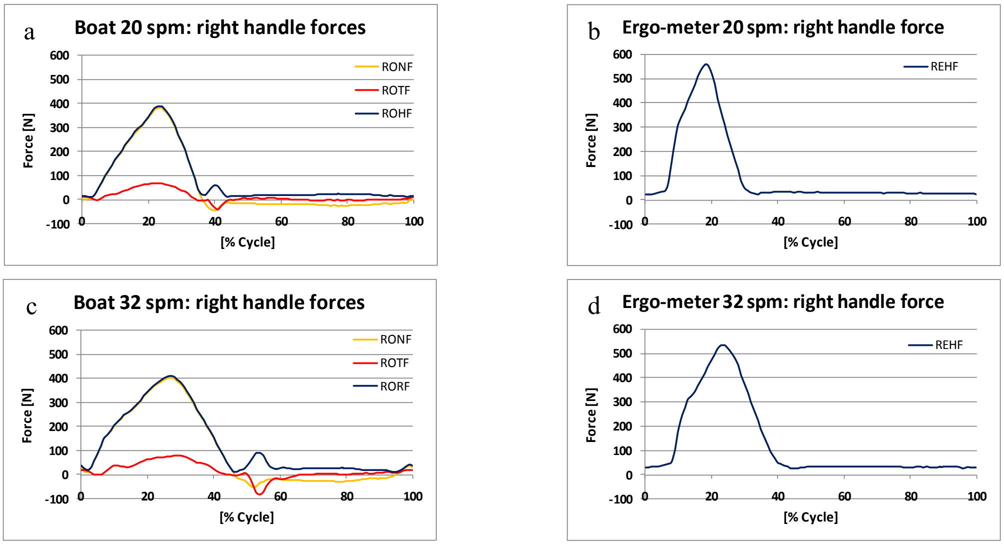


Fig. 4. (a) mean handle forces curves at 20 spm rowing on the boat; (b) mean handle force curve at 20 spm rowing on the ergo-meter; (c) mean handle forces curves at 32 spm rowing on the boat; (d) mean handle force curve at 32 spm rowing on the ergo-meter. Right oar normal force (RONF), right oar tangential force (ROTF), right oar resultant force (RORF), right ergo-meter handle force (REHF).

Table 1 and table 2 reported the peak values of kinematics, kinetics and normalized EMG. Further we reported the differences in % of ergo-meter data with respect to the values recorded on the boat. Peaks reported are the average among the 10 peaks detected on the stroke cycles analyzed.

Table 1. Peak values comparison between rowing on the boat and on the ergo-meter at 20 spm. Differences in % are calculated with respect to the boat values. Biceps brachii (BB); pectoralis maior (PM); deltoideus medialis (DM); trapezius trasversalis (TT); latissimus dorsi (LD); erector spinae (ERS); vastus medialis (VAM); biceps femoris (BF); resultant handle force (RHF).

	Kinematics [°]		EMG activity [% MVC]								Force [N]
	Elbow	Knee	BB	PM	DM	TT	LD	ERS	VAM	BF	RHF
Ergo-meter	126.1	76.6	43.7	75.7	92.9	83.4	106.2	257.9	262.5	143.7	557.2
Boat	104.8	80.2	28.3	250.6	66	69.5	121.3	282.5	179.3	167.8	388.4
Δ [%]	**+20.3**	**-4.5**	**+54.5**	**-69.8**	**+40.7**	**+20**	**-12.5**	**-8.7**	**+46.4**	**-14.3**	**+43.5**

Table 2. Peak values comparison between rowing on the boat and on the ergo-meter at 32 spm. Differences in % are calculated with respect to the boat values. Biceps brachii (BB); pectoralis maior (PM); deltoideus medialis (DM); trapezius trasversalis (TT); latissimus dorsi (LD); erector spinae (ERS); vastus medialis (VAM); biceps femoris (BF); resultant handle force (RHF).

	Kinematics [°]		EMG activity [% MVC]								Force [N]
	Elbow	Knee	BB	PM	DM	TT	LD	ERS	VAM	BF	RHF
Ergo-meter	122.6	75.2	39.1	99.4	91.1	85.8	97.9	241.1	254	136.7	533.3
Boat	105.1	77.4	29.1	269.5	70.9	75.2	109.6	274.2	281.8	157.7	410.7
Δ [%]	**+16.6**	**-2.8**	**+34.3**	**-63.1**	**+28.6**	**+14**	**-10.7**	**-12.1**	**-9.9**	**-13.3**	**+29.8**

Cross-plots of elbow and knee flexion versus muscle activity and versus resultant handle force showed different coordinative patterns comparing the two experimental conditions independently from the spm number (Figure 5). In particular the peak force was recorded with elbow extended in the boat and with elbow flexed in the ergo-meter. Vastus medialis was activated mostly at the beginning of the push phase rowing on the ergo-meter while on the boat its activation was more distributed during all the push phase. Erector spinae showed a higher activation on the boat at the end of the push phase while with the ergo-meter its activity was more intensive in the middle of the push phase. Considering the EMG activity of the biceps femoris, it reached its peak earlier rowing on the ergo-meter than rowing on the boat. On the boat deltoideus medialis showed an activation also in the recovery phase. This was not detected in the ergo-meter.

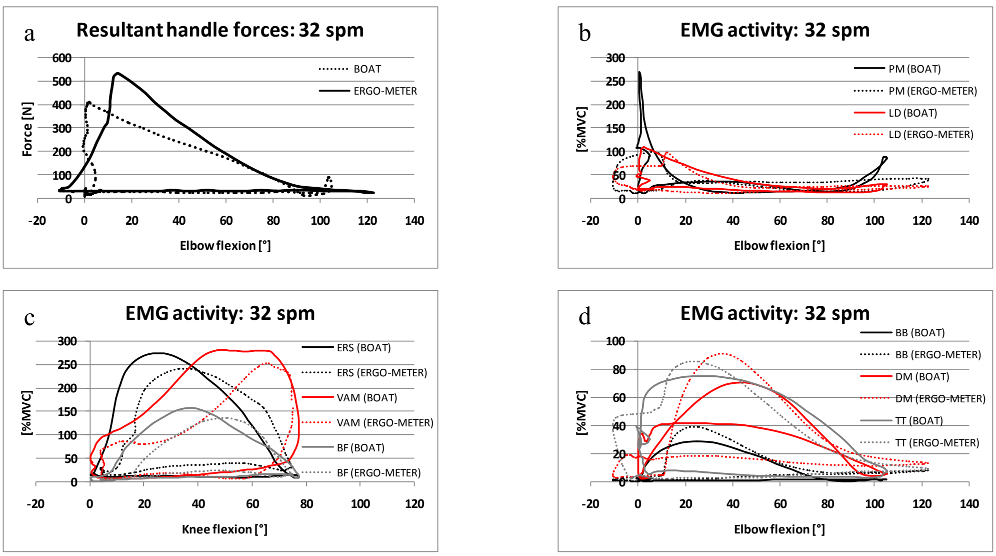


Fig. 5. Cross-plots of elbow and knee flexion versus handle force and versus muscle activity at 32 spm. Biceps brachii (BB); pectoralis maior (PM); deltoideus medialis (DM); trapezius trasversalis (TT); latissimus dorsi (LD) erector spinae (ERS); vastus medialis (VAM); biceps femoris (BF)

4. Discussion and conclusion

Results of this preliminary study indicated the ergo-meter as a valid training device considering the higher values of handle force measured with respect to rowing on the boat. Moreover higher values of EMG were collected for the biceps brachii (BB), deltoideus medialis (DM), trapezius trasversalis (TT), and vastus medialis (VM). However, rowing on the boat showed a higher EMG activity for the pectoralis maior (PM), latissimus dorsi (LD) and biceps femoris (BF). Taking together these considerations, in the period where athletes extensively employed the ergo-meter, they should also adopt resistance training programs for those muscle not properly activated on the simulator.

Cross-plots of knee and elbow flexion versus EMG muscle activities and versus handle force showed different coordinative patterns comparing the two experimental conditions suggesting a careful employment of the ergo-meter close to competitions not to alter the stroke technique.

Finally the results of this preliminary pilot study let suppose that tests on the ergo-meter should be used to predict the metabolic capacity of the athlete (maximal oxygen consumption, anaerobic threshold, …) more than to evaluate his rowing technique. Further researches with a convenient sample size are needed to confirm these promising preliminary results.

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